



*The **SAFEST WATER** In The World*

Final Report for New Mexico Water Quality Management Program (NMWQMP) June 2010

Solving the funding and water quality inequalities between our New Mexico's small and large communities requires unique solutions. By all definitions the Water Quality New Mexico Program ("WQNM" or "Program") is a unique solution, and has proven to be both challenging and rewarding.

Overall MIOX is pleased with the Program's success, and we look forward to implementing a similar yet improved model across many more of New Mexico's rural communities. We feel WQNM could allow New Mexico to pioneer a fresh approach to solving a historical problem.

Through WQNM, the New Mexico Environmental Department ("NMED") has proven that sophisticated technology is deployable into New Mexico's rural communities, and shown that working with private service and technology partners can help communities gain compliance in critical areas such as disinfection-byproducts ("DBPs").

Through this "pilot" phase of the Program MIOX has developed a set of "lessons learned" that can be used to improve during the expansion phase of this Program.

While improvements can be made, treating the Program as a Service turns out to be a great approach. Communities had/have a healthy level of "skin in the game", with the State and MIOX maintaining oversight in the areas (including automated systems, onsite equipment service, and commodity deliveries).

1). Sampling. Sampling was an issue, particularly in light of the addition of heterotrophic plate counts ("HPC") on top of standard, regulated chlorine residuals and Disinfection Byproducts ("DBP"). While the HPCs were important to validate the performance of MIOX's Mixed-Oxidant chlorine chemistry, it was extremely difficult to get the communities and lab to adhere to the sampling instructions. While we all agreed getting more "skin in the game" from each community participant, additional sampling responsibilities proved to be difficult one. In the future, additional planning will be required to ensure the right set of data is assembled to monitor success. In addition, we experienced multiple issues with the lab conducting the test results: 1) not sending out sample bottles

to sites; 2) ownership change mid stream; 3) multiple point of contact turnover; and 4) in the months of May and June 2010, shut down all sampling from any site - they cited it to be a corporate decision. I would recommend for future endeavors that the lab is engaged by all parties to ensure quality and responsibility. Consideration should be given to including the lab of choice in the MOU.

2). Stable team from start to finish. MIOX will be the first to admit it added unnecessary challenge to the execution of WQNM as a result of participant turnover. MIOX had no less than three (3) managers of the Program, through its life. Not only from the private enterprise partner, it is important to have identified team members involved from start to finish from the State as well. This should include specific members of the compliance authority that are responsible for oversight within the territories where each participant community is located, to reinforce the terms of agreement of the Program.

3). Periodic Audit. MIOX often found enforcement of the terms of the MOU agreement and direct recommendations to be difficult. Whether it be additional sampling, documentation, or simple maintenance requests, the responsibilities originally agreed to by community participants often fell into the hands of the MIOX service department. MIOX as the private enterprise partner has limited ability to make communities “do the work”, given the nature of the supplier / customer relationship, and limited Program authority. It is important to have the “backing” of the State’s compliance authorit(ies) to reinforce and / or step in with direct involvement to ensure these recommendations are (a) assessed, (b) reinforced, and (c) implemented. Or, alternatively, the private enterprise partner must be given the authority to discontinue the community’s participation in the Program. On the latter, this may be less effective given the private enterprise partner’s interest in maintaining a revenue-bearing relationship.

4). Extend length of Grant term. In order to get everything in order for WQNM entry for participant communities, it took much longer than initially anticipated for communities to gain entry into WQNM. We are coming to the end of the grant while the last entrant community is just starting the Program. As a result, initial delivery of the final report will be somewhat premature in that it will not encompass the full twelve (12) month period for some communities and nothing for the last community (Jemez Springs). The MIOX team will continue to execute against milestones and its responsibilities, and will retroactively update the final report. But, it would be helpful to have a period extension available, or to extend the period of the grant.



5). Assessing the capabilities of the private enterprise partner. As MIOX has traditionally operated through a representative network, and completed work with customers based on straight capital equipment purchases, the WQNM was a departure from standard business practices. As a result, this added to the challenges of the Program. It is important that the State assess capabilities required of the private enterprise partner, in order to ensure abilities match the scope of work intended.

6). “Skin in the Game” for Rural Communities. As with any subsidized program with direct State involvement, it is important that the community participants have “skin in the game.” The State and MIOX did a good job of assessing the responsibilities of the Program, and outlining responsibilities in the form of an MOU agreement. Nonetheless, it will be important to revisit the division of responsibilities for optimization. This includes any organization that will be involved, including such areas as the organization chosen to analyze samples.

Part Orders /Salt Consumption/FAC (Free Available Chlorine) Generation per Site:

- Salt calculations are approximate based on number of pallets delivered, not actual salt consumption
- Cost comparison: Standard bulk bleach delivered at 12% costs an average of \$2.50 per gallon.

Big Mesa: MIOX SAL 80 System 10 lbs/day FAC (Free Available Chlorine). MIOX On-Line 11/24/08

11/24/08 Pallet of Salt delivered at Commissioning

06/23/09 Domino Chip

07/09/09 Control Board/Pallet of Salt (49 bags per pallet, 50 lbs bags)

12/02/09 Pallet of Salt

02/03/10 Pressure Gauge

- Site required a heater due to incoming water temperatures of 40-42 degrees. Specification for this unit is 50-80 degrees.
- Pounds of salt consumed for Big Mesa 7350 lbs, approximately 20.1 salt/ lbs per day. Total FAC (Free Available Chlorine) generated 1531 lbs, approximately 4.2 lbs/day, 21.84 kwh (Electricity) per day.



- Salt cost per day \$6.83, Power cost per day \$1.22, Total cost per day \$8.05. Monthly cost to operate the system \$ 241.50. Yearly cost to operate the system \$2898.00.
- Estimated cost comparison - OSG (Onsite Generation) vs Bulk Bleach for Big Mesa: Approximate usage of Bulk Bleach per day 2.5 gallons /day multiplied by \$2.50 per gallon = \$6.25 cost per day to operate. Monthly cost to operate with Bulk Bleach = \$187.50. Yearly cost to operate using Bulk Bleach \$2250.00.
- Cost comparison using OSG (Onsite Generation) compared to Bulk Bleach. Estimated yearly cost comparison ** Bulk Bleach \$2250 vs OSG \$2898. ** No historical data was collected prior to the MIOX installation.
- Site was required to pull 220V (Volt), 1PH (Single Phase), 30A (Amp) service for the MIOX unit if they did not have it.
- Initial start up was a bit challenging due to space constraints, but we were able to overcome with the help and support of Jack Lemons and his staff. No major issues encountered during installation.
- Installation and Commissioning took approximately 2 week's (MIOX personnel), operator involvement/maintenance is approximately 2-3 hours per week, entries in daily log, maintenance checks, and adding salt to brine generator. ** No historical operations data was collected prior to the MIOX installation for comparison.
- Recommendations: Careful monitoring of FAC (Free Available Chlorine) as it leaves the treatment facility and at the end points in distribution. Each site to seek advanced chlorination training. MIOX personnel to assist with baseline and required sampling throughout the program. Each site will be required to attend MIOX technical training for an overall understanding of the MIOX system.

**Cimarron: MIOX SAL 80 System 10 lbs/day FAC (Free Available Chlorine).
MIOX On-Line 8/13/09**

04/29/09 Pallet of Salt (49 bags per pallet, 50 lbs bags)
07/27/09 Electrolytic Cell
02/01/10 Pallet of Salt

- Site required a heater due to incoming water temperatures of 32 degrees. Specification for this unit is 50-80 degrees.



- Pounds of salt consumed for Cimarron 4900 lbs, approximately 14.8 salt/lbs per day. Total FAC (Free Available Chlorine) generated 1020 lbs, approximately 3.1 lbs/day, 16.1 kwh (Electricity) per day.
- Salt cost per day \$5.03, Power cost per day \$.90, Total cost per day \$5.93. Monthly cost to operate the system \$ 177.90. Yearly cost to operate the system \$2134.80.
- Estimated cost comparison - OSG (Onsite Generation) vs Bulk Bleach for Cimarron: Approximate usage of Bulk Bleach per day 2 gallons /day multiplied by \$2.50 per gallon = \$5.00 cost per day to operate. Monthly cost to operate with Bulk Bleach = \$150.00. Yearly cost to operate using Bulk Bleach \$1800.00.
- Cost comparison using OSG (Onsite Generation) compared to Bulk Bleach. Estimated yearly cost comparison ** Bulk Bleach \$1800 vs OSG \$2134. ** No historical data was collected prior to the MIOX installation.
- Site was required to pull 220V (Volt), 1PH (Single Phase), 30A (Amp) service for the MIOX unit if they did not have it.
- Initial start up was a bit challenging due to space constraints, but we were able to overcome with the help of Leo Martinez and his staff. No major issues encountered during installation.
- Installation and Commissioning took approximately 2 week's (MIOX personnel), operator involvement/maintenance is approximately 2-3 hours per week, entries in daily log, maintenance checks, and adding salt to brine generator. ** No historical operations data was collected prior to the MIOX installation for comparison.
- Cimarron has implemented a flushing program to eliminate any residual bio-film in distribution lines. ** A biofilm is an aggregate of microorganisms in which cells adhere to each other and/or to a surface. These adherent cells are frequently embedded within a self-produced matrix of extracellular polymeric substance (EPS). Biofilm EPS, which is also referred to as slime, is polymeric conglomeration generally composed of extracellular DNA, proteins, and polysaccharides in various configurations.
- Recommendations: Careful monitoring of FAC as it leaves the treatment facility and at the end points in distribution. Each site to seek advanced chlorination training. MIOX personnel to assist with baseline and required sampling throughout the program. Each site will be required to attend MIOX technical training for an overall understanding of the MIOX system.



Miami: MIOX SAL 80 System 10 lbs/day FAC (Free Available Chlorine). MIOX On-Line 4/13/09

04/29/09 Pallet of Salt (49 bags per pallet, 50 lbs bags)
 06/09/09 Domino Chip for control board
 06/22/09 Reprogrammed Domino Chip
 02/01/10 Pallet of Salt

- Site required a heater due to incoming water temperatures of 35 degrees. Specification for this unit is 50-80 degrees.
- Pounds of salt consumed for Miami 4900 lbs, approximately 13.42 salt/lbs per day. Total FAC (Free Available Chlorine) generated 1020 lbs, approximately 2.79 lbs/day, 14.5 kwh (Electricity) per day.
- Salt cost per day \$4.56, Power cost per day \$.81, Total cost per day \$5.37. Monthly cost to operate the system \$ 161.10. Yearly cost to operate the system \$1933.20.
- Estimated cost comparison - OSG (Onsite Generation) vs Bulk Bleach for Miami: Approximate usage of Bulk Bleach per day 2 gallons /day multiplied by \$2.50 per gallon = \$5.00 cost per day to operate. Monthly cost to operate with Bulk Bleach = \$150.00. Yearly cost to operate using Bulk Bleach \$1800.00.
- Cost comparison using OSG (Onsite Generation) compared to Bulk Bleach. Estimated yearly cost comparison ** Bulk Bleach \$1800 vs OSG \$1933. ** No historical data was collected prior to the MIOX installation.
- Site was required to pull 220V (Volt), 1PH (Single Phase), 30A (Amp) service for the MIOX unit if they did not have it.
- Initial start up was a bit challenging due to space constraints, but we were able to overcome with the help of Mike Vigil and his staff. No major issues encountered during installation.
- Installation and Commissioning took approximately 2 week's (MIOX personnel), operator involvement/maintenance is approximately 2-3 hours per week, entries in daily log, maintenance checks, and adding salt to brine generator. ** No historical operations data was collected prior to the MIOX installation for comparison.
- Miami has had some intermittent issues with the solution tank overflowing. We believe this to be occurring due to a programming issue within the Domino chip or control board. We have worked and will continue to work with Mike to resolve the intermittent issue.
- Miami has implemented a flushing program to eliminate any residual bio-film in distribution lines. ** A biofilm is an aggregate of microorganisms in which cells adhere to each other and/or to a surface. These adherent cells are frequently



embedded within a self-produced matrix of extracellular polymeric substance (EPS). Biofilm EPS, which is also referred to as slime, is polymeric conglomeration generally composed of extracellular DNA, proteins, and polysaccharides in various configurations.

- **Recommendations:** Careful monitoring of FAC as it leaves the treatment facility and at the end points in distribution. Each site to seek advanced chlorination training. MIOX personnel to assist with baseline and required sampling throughout the program. Each site will be required to attend MIOX technical training for an overall understanding of the MIOX system.

Springer: MIOX RIO M1 60 lbs/day FAC (Free Available Chlorine). MIOX On-Line 8/20/09

06/22/09 Pallet of Salt (49 bags per pallet, 50 lbs bags)

08/05/09 3 Way Valve

10/21/09 Pallet of Salt

12/17/09 Pallet of Salt

03/02/10 Pallet of Salt

- Site required a heater due to incoming water temperatures of 40 degrees. Specification for this unit is 50-80 degrees.
- Pounds of salt consumed for Springer 9800 lbs, approximately 31.1 salt.lbs per day. Total FAC (Free Available Chlorine) generated 2940 lbs, approximately 9.3 lbs/day, 32.5 kwh (Electricity) per day.
- Salt cost per day \$10.57, Power cost per day \$1.82, Total cost per day \$12.39. Monthly cost to operate the system \$ 371.70. Yearly cost to operate the system \$4460.40.
- Estimated cost comparison - OSG (Onsite Generation) vs Bulk Bleach for Springer: Approximate usage of Bulk Bleach per day 5 gallons /day multiplied by \$2.50 per gallon = \$12.50 cost per day to operate. Monthly cost to operate with Bulk Bleach = \$375.00. Yearly cost to operate using Bulk Bleach \$4500.00.
- Cost comparison using OSG (Onsite Generation) compared to Bulk Bleach. Estimated yearly cost comparison ** Bulk Bleach \$4500 vs OSG \$4460. ** No historical data was collected prior to the MIOX installation.



- Site was required to pull 480V (Volt), 3PH (Three Phase), 100A (Amp) service for the MIOX unit, this was more challenging and time consuming for Springer which lead to a later commissioning date for the unit.
- Initial start up was challenging due to space constraints, power requirements, and tie in of plumbing through concrete walls. We were able to overcome with the help of Laura Danielson and her staff. No major issues encountered during installation.
- Installation and Commissioning took approximately 3-4 week's (MIOX personnel), operator involvement/maintenance is approximately 2-3 hours per week, entries in daily log, maintenance checks, and adding salt to brine generator. ** No historical operations data was collected prior to the MIOX installation for comparison.
- Springer has implemented a flushing program to eliminate any residual bio-film in distribution lines. ** A biofilm is an aggregate of microorganisms in which cells adhere to each other and/or to a surface. These adherent cells are frequently embedded within a self-produced matrix of extracellular polymeric substance (EPS). Biofilm EPS, which is also referred to as slime, is polymeric conglomeration generally composed of extracellular DNA, proteins, and polysaccharides in various configurations.
- Recommendations: Careful monitoring of FAC as it leaves the treatment facility and at the end points in distribution. Each site to seek advanced chlorination training. MIOX personnel to assist with baseline and required sampling throughout the program. Each site will be required to attend MIOX technical training for an overall understanding of the MIOX system.



BACKGROUND

The objective of the New Mexico Water Quality Management Program (NMWQMP) (the Program) is to determine whether and to what extent improvements in distribution water quality in small potable water treatment systems can be achieved using on-site generators (OSG) of a chlorine-based disinfecting solution manufactured by MIOX Corporation, Albuquerque, NM. Currently four small water systems are participating in the program as detailed in Table 1. A fifth participant – Jemez Valley Public Schools – is expected to be added in 2010 but too late to be included in this report, and the longest participant in the Program – the Big Mesa Mutual Domestic Water Commerce Association – is expected to have the assessment completed in 2010 and leave the Program.

This report includes the data on the two assessment parameters – Heterotrophic Plate Count (HPC) and the disinfection by-products Total Trihalomethanes (TTHMs) – for the four current participants.

PARTICIPANTS AND PROGRAM DETAILS

Table 1 Program Participants, MIOX Systems, and Dates MIOX Systems On-Line

System Participant	County	MIOX System		MIOX On-Line Date	Plant Superintendent	Sampling Locations	
		Model	Capacity lbs/day ⁵			HPC	TTHM
Big Mesa ¹	San Miguel	SAL80	10	11/24/08	Jack Lemons	3	1
Miami ²	Colfax	SAL80	10	4/13/09	Mike Vigil	3	1
Cimarron ³	Colfax	SAL80	10	8/13/09	Leo Martinez	3	1
Springer ⁴	Colfax	RIO M1	60	8/20/09	Laura Danielson	3	1

¹ Big Mesa Mutual Domestic Water Commerce Association; NM3573725; Conchas Dam Intake

² Miami Water users Association; NM3526504; Intake #1 (reservoir unknown)

³ Cimarron Water System; NM3526204; Cimarroncito Reservoir Intake

⁴ Springer Water System; NM3526604; Lower Reservoir Intake (reservoir unknown)

⁵ Capacity in pounds of measured Free Available Chlorine (FAC) per day

Samples for HPC analyses are collected by plant personnel at three distribution system locations on a monthly or greater schedule. HPC analyses are conducted according to Standard Methods¹ Method 9215 D Membrane Filter Method at Assaigai Laboratories, later ARS Analytical, LLC, with some analyses subcontracted to Hall Environmental.

TTHM measurements at one distribution system location for each participant were retrieved from the NMED website <https://eidea.nmenv.state.nm.us/SDWIS/>. Samples are collected quarterly from one location in the distribution system of each participant as part of the State required monitoring program. Analyses were conducted according to US EPA Method 524.2 Purge and Trap with Gas Chromatography/Mass Spectrometry (P&T/GC/MS). TTHM analyses have been conducted at various laboratories including Scientific Lab Division, Flowers, and Swat Laboratories.

¹ American Public Health Association, American Water Works Association, and Water Environment Federation, 2005, *Standard Methods for the Examination of Water and Wastewater*, 21st Edition, APHA, Washington, DC.



SUMMARY OF DATA FOR PARTICIPATING SYSTEMS

Heterotrophic Plate Count

The Heterotrophic Plate Count (HPC), formerly known as the standard plate count, measures the presence in a water sample of heterotrophic bacteria – those which obtain energy by oxidizing organic matter and use the organic compounds as a carbon source in their own structures. The majority of bacteria, both pathogenic and non-pathogenic, are heterotrophic². Because of its lack of specificity, the HPC has not been used to assess the likelihood of waterborne disease as a specific HPC count may contain many, few or no pathogens. A high HPC may indicate poor general biological quality of a drinking water. Under US EPA regulations, distribution systems that have no detectable disinfectant residual may claim, for the purposes of the regulations, that disinfectant is present if the HPC does not exceed **500** colony forming units (cfu) per milliliter of sample (cfu/mL)³. With adequate disinfection, baseline HPC levels can easily be maintained at 10 to 100 cfu/mL. When normal background HPC levels become greater than 1000 cfu/mL, action should be initiated immediately to resolve the microbial growth problem including flushing and boosting of disinfectant levels⁴.

The HPC is typically used to help fine-tune water treatment plant (WTP) operation and distribution system maintenance. If HPC measurements are “low”, the WTP is likely maintaining a “clean” process and distribution system. If the HPC measurements are “high”, there may be room for improvement in the treatment process, or there may be bacteriological regrowth occurring in the distribution system, which *may* indicate the presence of a biofilm. HPC results are indicative only, and may not indicate the potential for any actual problems or health impacts. Nevertheless, the HPC can be a useful tool in tracking performance of the WTP and microbiological cleanliness in the distribution system.

Big Mesa

The MIOX system at Big Mesa came on-line 24 November 2008. Samples for HPC measurements were collected on 20 November to provide a baseline and samples have been collected since at three locations in the distribution system at approximately 2-month intervals to assess the effects of the MIOX system. HPC testing results to date are shown in Table 2.

Table 2 HPC Testing Results for Big Mesa

Sampling Date	Results (cfu/mL)		
	Sampling Location		
	Big Mesa	Harbor	Yucca
11/20/2008	69	251	110

² Droste, R.L., 1997, *Theory and Practice of Water and Wastewater Treatment*, John Wiley and Sons, Inc., New York, NY, 800 pp.

³ Cohn, P.D., M. Cox, and P.S. Berger, 1999, “Health and Aesthetic Aspects of Water Quality”, Chapter 2 in *Water Quality and Treatment: A Handbook of Community Water Supplies*, Fifth Edition, American Water Works Association, R.D. Letterman, Technical Editor, McGraw-Hill, Inc., New York, NY.

⁴ Geldreich, E.E. and M. LeChevallier, 1999, “Microbiological Quality Control in Distribution Systems”. Chapter 18 in *Water Quality and Treatment: A Handbook of Community Water Supplies*, Fifth Edition, American Water Works Association, R.D. Letterman, Technical Editor, McGraw-Hill, Inc., New York, NY.



1/14/2009	ND	ND	50
3/25/2009	ND	ND	ND
7/08/2009	20	50	35

The baseline HPC results (not highlighted) for the Big Mesa, Harbor and Yucca sites were 69, 251, and 110 colony forming units per milliliter (cfu/ml) respectively suggesting that the disinfection residual present prior to the MIOX system installation was providing adequate disinfection. After approximately 100 days of dosing the MIOX mixed-oxidant solution (MOS) into the system, the HPC measurements were Non-Detect (ND) across all three locations. Subsequent samples show detections but at lower levels than the baseline. It is likely that the detections in the 8 July 2009 samples are caused by warm weather and release of biofilms from the system. Sampling locations are ordered by distance from the WTP (Water Treatment Plant) – Big Mesa 1 mile; Yucca 1.5 miles; Harbor 2 miles.

Big Mesa apparently stopped sampling for HPC measurements after the 8 July 2009 round as no new measurement data have been received since the quarterly report on this project in January 2010.

Miami

The MIOX system at Miami came on-line 13 April 2009. Unfortunately no samples for HPC measurements were collected prior to this date; thus no baseline for comparison is available. HPC testing results to date are shown in Table 3. Sampling locations are ordered by distance from the WTP (Water Treatment Plant) – #31 approximately 1 mile; #16 approximately 1.25 miles; #23 approximately 2.5 miles.

Table 3 HPC Testing Results for Miami

Sampling Date	Results (cfu/mL)		
	Sampling Location		
	#31	#16	#23
5/19/2009	>2000	ND	ND
6/17/2009	ND	ND	10
7/22/2009	10	10	20
9/30/2009	>2000	ND	ND
11/05/2009	20	ND	ND
12/08/2009	2	ND	2
2/02/10	10	ND	ND
3/15/10	2	ND	ND

The HPC testing results generally indicate that the system is clean, i.e. easily meeting the criterion of <500 cfu/mL for all sampling locations except #31. The two extremely high HPC measurements at location #31 may represent sporadic release of biofilm accumulated prior to use of MIOX MOS. The low values of HPC at all locations in the last two samples, collected since the quarterly report on this project in January 2010, support the hypothesis that the two extremely high values seen earlier at location #31 were indeed caused by releases of biofilm accumulated prior to the MIOX system installation. Results indicate that the distribution system has remained “clean” since 30 September 2009.



Cimarron

The MIOX system at Cimarron came on-line 13 August 2009. Unfortunately no samples for HPC measurements were collected prior to this date; thus no baseline is available. As of the quarterly report on this project in January 2010, no samples for HPC measurements had been collected.

Samples were collected on 8 April 2010 at City Yard, City Park, and Ponil Campground in the Village of Cimarron. Results showed no detections (ND) in the three samples. The distribution system may be considered “clean”, i.e. easily meeting the criterion of <500 cfu/mL for all sampling locations. Sampling locations are ordered by distance from the WTP (Water Treatment Plant) – City Yard approximately 1 mile; City Park approximately 1.5 miles; Ponil Campground approximately 2.25 miles.

Springer

The MIOX system at Springer came on-line 20 August 2009. Unfortunately no samples for HPC measurements were collected prior to this date; thus no baseline for comparison is available. Two samples for HPC measurement have been collected. Results are shown in Table 4.

Table 4 HPC Testing Results for Springer

Sampling Date	Results (cfu/mL)		
	Sampling Location		
	Colfax Genl	City Hall	City Shop
12/22/2009	130	10	ND
4/15/2010	10	10	3

The HPC testing results generally indicate that the system is clean, i.e. easily meeting the criterion of <500 cfu/mL for all sampling locations. Sampling locations are ordered by distance from the WTP (Water Treatment Plant) – City Hall approximately 2 miles; City Shop approximately 3 miles; Colfax approximately 3.5 miles.

Total Trihalomethanes (TTHMs):

The disinfection by-products (DBPs) in potable water that are regulated by US EPA and the State of New Mexico include Total Trihalomethanes (TTHMs) and five of the nine possible Haloacetic Acids (termed HAA5s). Historic TTHM data are available for all four sites and historic HAA5 data are available for three of the sites.

The historic TTHM data are more regular with time, indicate better quality control in sampling and analyses, and typically vary over time within a factor of 10.

Trihalomethanes (THMs) are a category of disinfection by-products formed when chlorine reacts with some forms of organic matter present in the water; the major precursor organic compounds for the formation of the THMs are known to be Humic and Fulvic acids, natural products of vegetation



decomposition⁵. However, THMs are also formed by reactions between FAC and biofilms⁶ and the presence of biofilms in distribution cause both the loss of FAC residual and the formation of THMs in the water.

The four THMs are chloroform (CHCl_3), bromodichloromethane (CHBrCl_2), dibromochloromethane (CHBr_2Cl) and bromoform (CHBr_3); the sum of the concentrations of these three species is the Total THMs, or TTHMs. The brominated species of the THMs form when bromide (Br^-) is present in the raw water and increase in relative fraction as the Br^- concentration in the raw water increases. At constant precursor organic compound concentrations and FAC residuals, THM formation increases with temperature. These by-products are listed as potentially cancer-causing when at high concentrations and under long-term exposure. As a result, they are regulated by US EPA and the State at a Maximum Contaminant Level (MCL) of 80 $\mu\text{g/L}$.

It has been observed in other potable water systems that the use of MIOX MOS can reduce the formation of DBPs (including TTHMs) at the plant and, more significantly, by removing biofilms from the distribution system. Removal of biofilms results in improved FAC residual maintenance in distribution, enabling a reduction in FAC dosing at the WTP⁷. By careful attention to MOS dosing and FAC residuals in distribution, previous high TTHM concentrations can be controlled to within the MCL requirements⁸.

⁵ Krasner, S.W., 1999, "Chemistry of Disinfection By-Product Formation", Chapter 2 in *Formation and Control of Disinfection By-Products in Drinking Water*, Philip C. Singer, Ed., American Water Works Association, Denver, CO.

⁶ Rossman, L.A., R.A. Brown, P.C. Singer, and J.R. Nuckols, 2001, "DBP Formation Kinetics in a Simulated Distribution System", *Wat. Res.*, 35(14):3483-3489.

⁷ Bradford, W.L., 2009, "The Differences between On-Site Generated Mixed-Oxidant Solution and Sodium Hypochlorite" aka "The Master Features Summary", MIOX Corporation, Albuquerque, NM, last updated 26 August 2009.

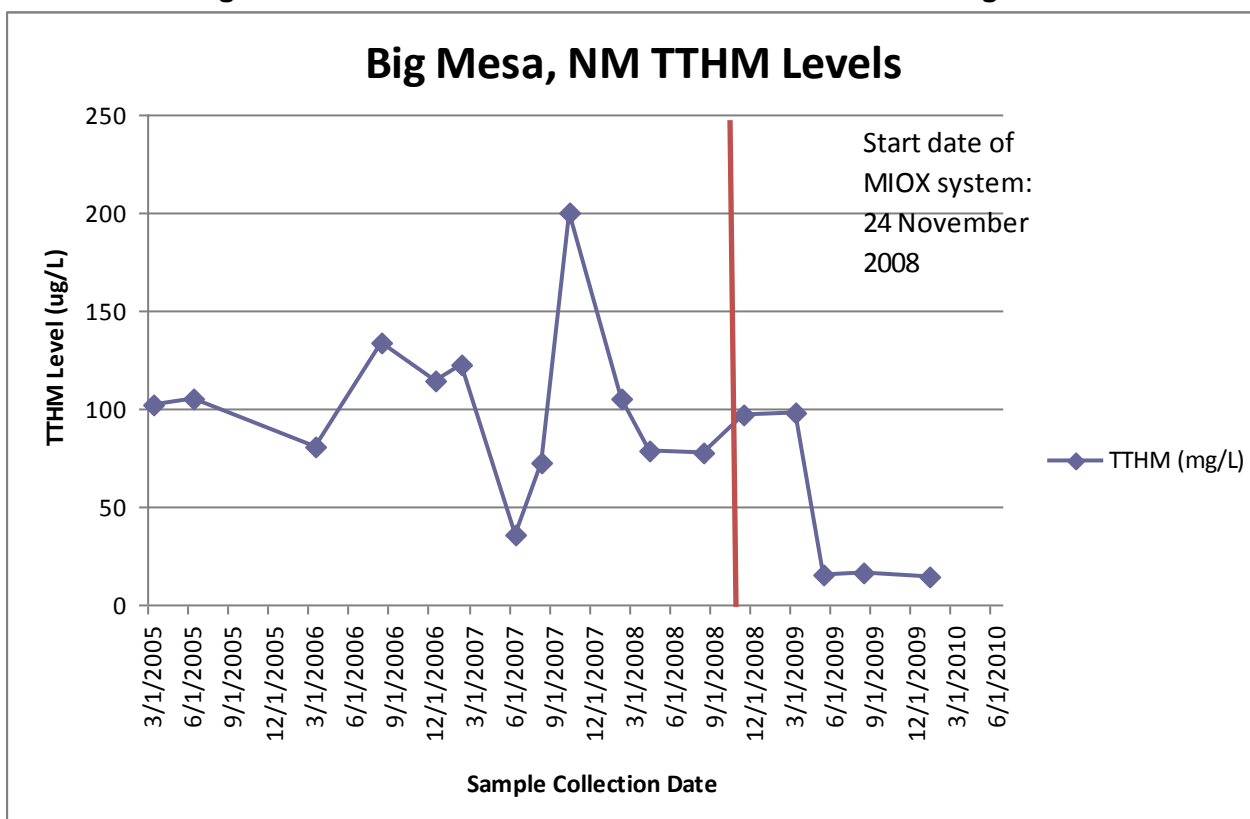
⁸ Bradford, W.L., 2009, "IMPORTANT PROJECTS IN MIOX APPLICATIONS — West Columbia, SC", initial compendium 23 November 2007; update 5 June 2009, MIOX Corporation, Albuquerque, NM.



Big Mesa

Historic and current TTHM concentrations at Big Mesa are shown in Figure 1.

Figure 1 Historic and Current TTHM Measurements at Big Mesa



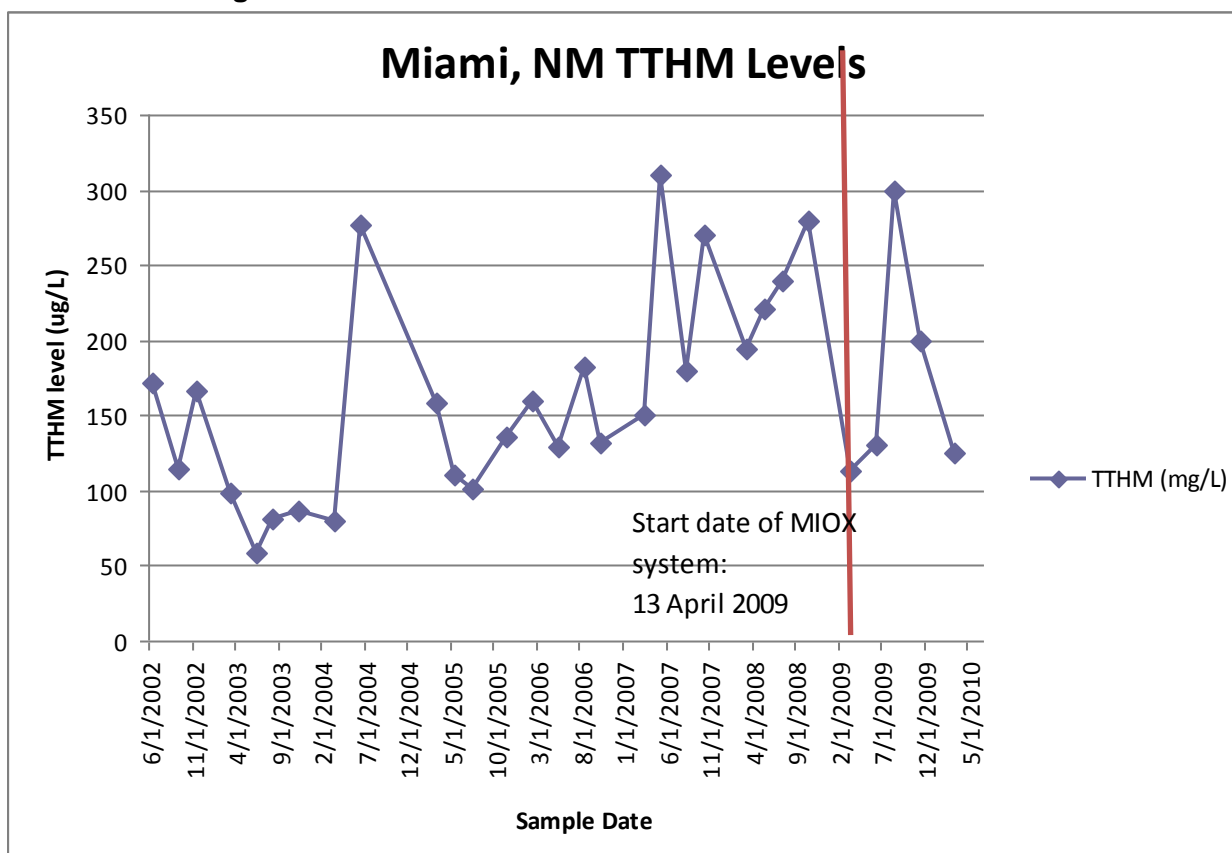
Historically, Big Mesa has been out of compliance with the MCL for TTHMs frequently. Five data points obtained since the installation of the MIOX system suggest considerable improvement. And the large *decreases* in TTHM concentrations occurred in warmer months – May and August – when increases would have been expected given constant precursor concentrations. The pattern of lower TTHM concentrations continued through the sample collected 25 January 2010.



Miami

Historic and current TTHM concentrations at Miami are shown in Figure 2.

Figure 2 Historic and Current TTHM Measurements at Miami



Historically, Miami has been out of compliance with the MCL for TTHMs for most of the past 8 years, and TTHM concentrations have been rising steadily since 2005. The first three of the four measurements made since the MIOX MOS started to be used did not show significant improvement. Analysis of the most recent sample, collected 18 March 2010, however suggests that TTHM concentrations may be trending lower although the value is still not in compliance with the MCL.

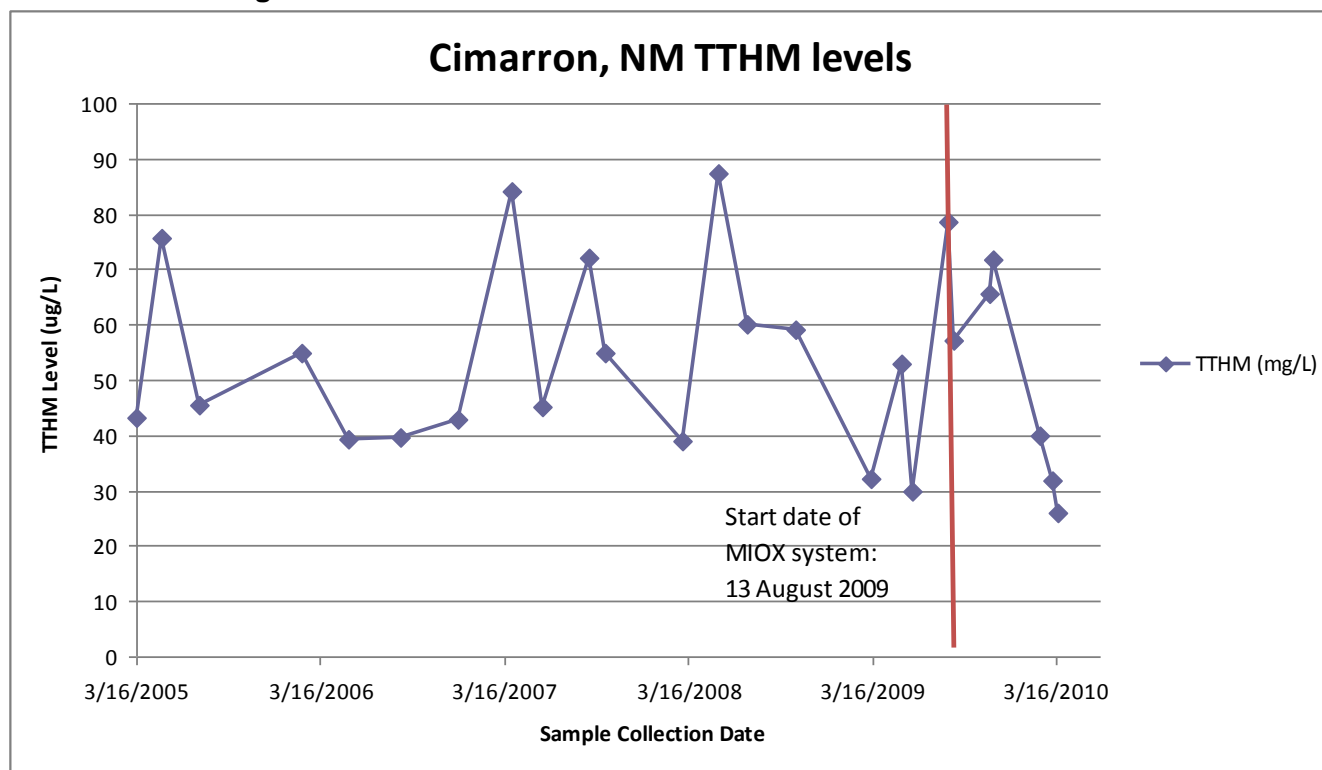
Evidence from the HPC measurements suggests significant biofilm presence in some areas of the distribution system through 30 September 2009 and a trend toward biofilm removal (lower HPC values) in subsequent samples. It is possible that TTHM concentrations will continue to trend downward since biofilm removal from the distribution system appears to have been accomplished.



Cimarron

Historic and current TTHM concentrations at Cimarron are shown in Figure 3.

Figure 3 Historic and Current TTHM Measurements at Cimarron



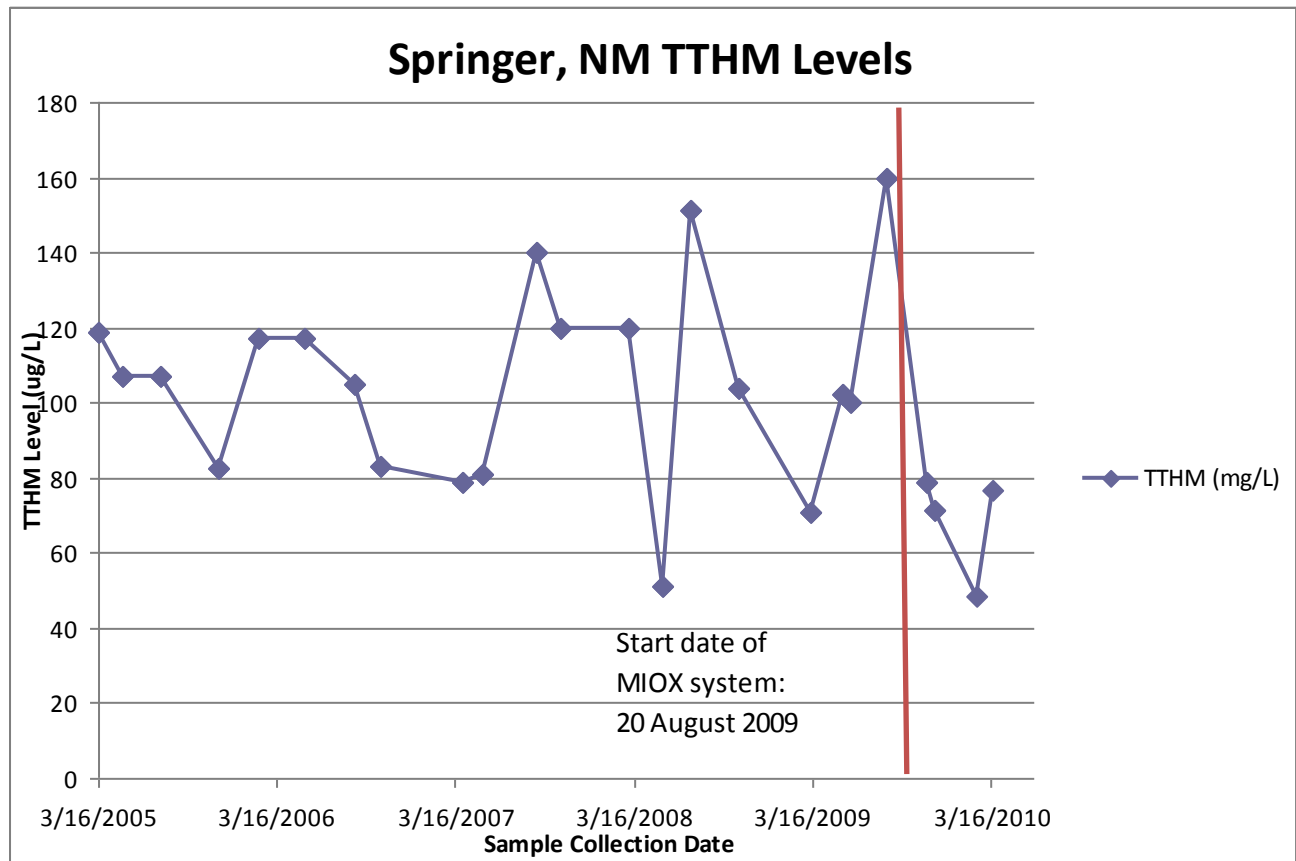
The TTHM concentrations at Cimarron have generally been in compliance with the MCL. The six data points taken since the MIOX system came on-line suggest continued compliance. The recent downward trend in TTHM concentrations suggests that MIOX MOS may be having a beneficial effect *possibly* due to removal of biofilm from the distribution system; unfortunately, the lack of baseline data on HPC levels for Cimarron obviates any stronger assertion as to a relationship between biofilm removal and TTHM reductions. Nevertheless, the TTHM concentration in the sample collected 18 March 2010 is the lowest value ever reported for Cimarron.



Springer

Historic and current TTHM concentrations at Springer are shown in Figure 4.

Figure 4 Historic and Current TTHM Measurements at Springer



Historically, Springer has been out of compliance with the MCL for TTHMs for most of the past 4 years. The historic data shows no obvious pattern with season – high concentrations occur in both warm summer month and cold winter months. The four measurements made after the MIOX system came on-line show an encouraging decline in the TTHM concentrations to below the MCL, concentrations achieved only twice in the 4 years prior to installation of the MIOX system.



CONCLUSIONS:

- Subsequent to the MIOX systems coming on-line, HPC levels in distribution system samples appear to have been reduced to lower levels – often to Non Detected (ND) – at Big Mesa and Miami. HPC analysis at Cimarron and Springer also suggest low levels, well below the criterion of <500 cfu/mL for “clean” distribution systems.
- TTHM analyses of samples collected since the MIOX systems came on-line at all four study sites have shown encouraging downward trends. As seen in samples taken at Big Mesa, Cimarron and Springer, TTHM concentrations appear to have been reduced to historic low levels.
- At Miami, although recent samples show an encouraging downward trend, the TTHM concentrations are so high that the use of MIOX MOS alone may not be sufficient to bring the system into compliance with the MCLs. Additional assistance in optimizing the treatment, storage and distribution systems may be required.
- Downward trends in the TTHM concentrations at all four study sites appear to be associated with downward trends in the HPC concentrations, supporting the hypothesis of a relationship between biofilm in the distribution systems and production of TTHMs.

RECOMMENDATIONS

- Dosing of MOS for disinfection should be based on actual measurements of both Free Available Chlorine (FAC) and Total Chlorine (TC) at the point of dosing and in distribution. Measurements should be made regularly by system operators. Actual measurements would enable more careful control on dosing, avoiding unnecessary overdosing and thereby minimizing the formation of disinfection by-products (DBPs).
- Both FAC and TC measurements should be made in distribution. Any difference between the two measurements in the absence of inorganic ammonia ($\text{NH}_3\text{-N}$) signal the presence of organic nitrogen (organic-N) which is present in biofilms. Thus any difference between the two measurements is an indication of the presence of biofilm in the distribution system.
- The Heterotrophic Plate Count (HPC) is a good but approximate measure of the general “cleanliness” of the distribution system, but it is not a particularly good measure of the potential presence of biofilm in the system. There are few if any biofilm indicators short of direct observation and assays for specific known biofilm-forming microorganisms. A new test kit from Hach Company – known as BART (Biological Activity Reaction Test) – includes a test having growth media specific for known biofilm-forming microorganisms (the test is named SLYM). Initial evaluation suggests that this test is more specific for biofilm-forming microorganisms than the HPC and can be done in the field by the operator.
- Measurements of temperature, FAC and TC should be made at the time and location of the collection of samples for DBP analysis. These measurements will help in the interpretation of both TTHM and HAA5 concentration variations with time in distribution.

Sincerely,

Steve Garcia/Chris Traylor
MIOX Corporation

